



## NIOSH Science Blog

# The Physiological Burden of Prolonged PPE Use on Healthcare Workers during Long Shifts

Posted on June 10, 2020 by Jon Williams, PhD; Jaclyn Krah Cichowicz, MA; Adam Hornbeck, MSN, APRN, FNP-BC, FNP-C; Jonisha Pollard, MS, CPE; and Jeffrey Snyder, MSN, CRNP.

Healthcare workers (HCW) and first responders often work long, physically and mentally exhausting shifts as they provide care for patients, especially during a public health emergency. These long hours can result in fewer adequate breaks for personal care, nutrition, and hydration. During these extended work shifts, many HCWs are also required to wear personal protective equipment (PPE), which may include N95 filtering facepiece respirators (FFRs) elastomeric half-mask respirators, or powered air-supplied respirators (PAPRs). Particular features of PPE can impose a physiological (how the body normally functions) burden on the HCW which can be exacerbated by long work hours without adequate breaks for eating, hydration and self-care.

While every HCW should be medically cleared before wearing respiratory protection, there are still many factors that can exacerbate the PPE burden, including obesity, underlying respiratory conditions (asthma, allergies, COPD, etc.), and smoking. HCWs should be provided regular opportunities to take breaks and a supportive environment to report symptoms related to their PPE use. For example, using an FFR for an extended period may cause dizziness (as well as other symptoms), which could compromise the worker, workplace, and patient safety. Dizziness is an important warning sign, as it can be caused by dehydration, hyperventilation (gasping for breath), elevated carbon dioxide [CO<sub>2</sub>] levels in the blood, low blood sugar, and anxiety, among other things.

Respirator wearers should be aware of the potential physiological impact of using each type of respirator.

### Filtering Facepiece Respirators

An N95 FFR user is always going to experience some level of difficulty breathing, or breathing resistance, even though these devices are designed to minimize breathing resistance as much as possible. Enough breathing resistance could result in a reduction in the frequency and depth of breathing, known as hypoventilation (the opposite of hyperventilation).

Hypoventilation is a primary cause of significant discomfort while wearing an N95 FFR (Williams 2010). However, studies done by Roberge et al. (2010) indicated that this hypoventilation did not pose a significant risk to healthcare workers over the course of less than one hour of continuous N95 use. When HCWs are working longer hours without a break while continuously wearing an N95 FFR, CO<sub>2</sub> may accumulate in the breathing space inside of the respirator and continuously increase past the 1-hour mark, which could have a significant physiological effect on the wearer (Lim et al., 2006). Some of the known physiological effects of breathing increased concentrations of CO<sub>2</sub> include:

1. Headache;
2. Increased pressure inside the skull;
3. Nervous system changes (e.g., increased pain threshold, reduction in cognition – altered judgement, decreased situational awareness, difficulty coordinating sensory or cognitive, abilities and motor activity, decreased visual acuity, widespread activation of the sympathetic nervous system that can oppose the direct effects of CO<sub>2</sub> on the heart and blood vessels);
4. Increased breathing frequency;
5. Increased “work of breathing”, which is result of breathing through a filter medium;
6. Cardiovascular effects (e.g., diminished cardiac contractility, vasodilation of peripheral blood vessels);
7. Reduced tolerance to lighter workloads.

To fix the problem of breathing too much CO<sub>2</sub> that has built up within the respirator facepiece, a worker can simply

remove the respirator. Some facilities practice oxygen supplementation during these breaks from respirator use, but there really is no need for this as the oxygen in the environment is more than enough to relieve most of the symptoms listed above.

### **Elastomeric Respirators**

The effects experienced with FFRs may also occur when wearing elastomeric half-mask respirators (EHMRs), which are a reusable type of respirator with a silicone facepiece and replaceable filter cartridges. Because they are reusable, EHMRs are a highly recommended alternative to the disposable N95 FFRs (Hines et al., 2019). However, the physiological burden on the wearer is more likely to cause anxiety when wearing an elastomeric respirator when compared to FFRs (Wu et al., 2011). The increased breathing resistances found in EHMRs can result in a decreased frequency of breathing and an increase in tidal volume (the air displaced between normal inhalation and exhalation).

In addition, studies have shown that using EHMRs with a greater resistance to breathing have resulted in the wearer breathing less oxygen (O<sub>2</sub>) and more CO<sub>2</sub> (Roberge et al., 2010), which can cause elevated CO<sub>2</sub> levels in the blood. The issues surrounding the use of elastomeric half-mask respirators in healthcare settings is discussed in further detail in a National Academies of Sciences report (Ref. 8).

### **Powered Air Purifying Respirators**

Another reusable alternative to N95 FFRs is the Powered Air-Purifying respirator (PAPR). The physiological benefit of PAPRs is that they have a fan that blows fresh air through the filter; therefore, there should not necessarily be any sense of breathing resistance as experienced with an N95 FFR or an elastomeric respirator. Because of this, wearing a PAPR would not cause either shortness of breath or hypoventilation, which may contribute to the increase in CO<sub>2</sub> in the breathing space. However, there may be other psychophysiological (the way in which the mind and body interact) effects resulting from the constant noise produced by the PAPR motor, such as headache, distraction, anxiety, difficulty communicating with others in the room to mention a few.

## **Perspective**

Studies have shown that HCWs prefer wearing N95 FFR respirators to wearing elastomeric half mask respirators or PAPRs when considering comfort and the ability to communicate, HCWs perceive EHMRs and PAPRs to provide greater protection in higher threat environments (e.g., during pandemics) and prefer these respirators to the N95 FFR in spite of the limitations of comfort and reduced ability to communicate. The limitations are tolerated for the purpose of greater perceived protection.

## **Tips for HCW Health Awareness**

### **Self-care**

While workers must concentrate on their important job duties and the proper use of PPE for self-protection, they must also be aware of the impact of PPE on their wellbeing. The balance between the protection afforded by PPE and the burden of that PPE must be met with a plan to mitigate the burden.

### **Take scheduled breaks**

Find a safe place to properly take off the respirator to reduce CO<sub>2</sub> build-up and the negative physiological effects associated with it.

Breaks during work shifts are vital to worker health and safety. The potential physiological burden brought on by PPE use can be an unfortunate side effect; however, it can easily be remedied with a little fresh air and proper self-care.

### **Hydrate and eat**

Dehydration can be a significant problem when wearing PPE while working in high threat environments. The effects of dehydration may contribute to the experience of the physiological burden such as headache, dizziness, strong sensation of thirst, and reduced cognition or greater distraction from the job. Therefore, HCWs must be aware of the need for

proper hydration especially if wearing PPE causes significant sweating from heat exposure. A rule of thumb is to drink 1 ml or 1 oz of fluid for every 1 ml or 1 oz of body weight lost. For example, if the HCW has lost 1lb of body weight they must drink 16 oz of fluid (or for metric, if the HCW has lost 1 kg of body weight, then they must consume 1000 ml of fluid to make up for the loss).

Similarly, one must eat healthy food in part because the calories are needed to provide energy for HCWs to continue their work and also because most food contains water which will help with re-hydrating the body.

#### **Institute policies to care for employees**

Supervisors and hospital management can minimize the physiological burden of PPE by instituting policies and procedures to assure breaks for HCWs, encouraging front-line supervisors to check in regularly with staff to assess for symptoms or concerns, and providing a mechanism to report symptoms immediately and without fear of penalty.

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This is a concise, informative and very well done essay with straight forward, logical advice. Thank you!

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It should be noted that the finding that elastomeric respirator use may result in the wearer breathing less oxygen (O<sub>2</sub>) and more CO<sub>2</sub> is also found in N95 use. This is not isolated to elastomeric respirators and has been reported in Roberge 2010 (reference 2).

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In the construction industry we frequently use N95 respirators for dust and particulate protection. We learned long ago that people get more tired when they work while wearing a respirator. As PPE is the third line of defense we rely more on Engineering and Administrative controls.

[Reply](#)

Very informative and interesting essay. Totally agree that Engineering and administrative control should be considered. The balance between manpower shortage and long duty hours is really a challenge.

[Reply](#)

Thanks for writing on the physiological burden of prolonged PPE use on healthcare workers. There is also a mental health burden component as healthcare workers with PPEs may not feel the connection with the patients and patients without seeing the healthcare workers' facial expression will feel alienated, worried and may become non-compliant to directions. It will be good if someone can cover that not any less important issue here.

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